Geotechnical Design of Foundations

This document implements foundation design compliant with EN 1990. The scenario is based on Eurocode 7: Geotechnical Design Worked Examples ANNEX A.2.

References:
- Eurocode 7: Geotechnical Design Worked examples
- EN 1997
- EN 1990

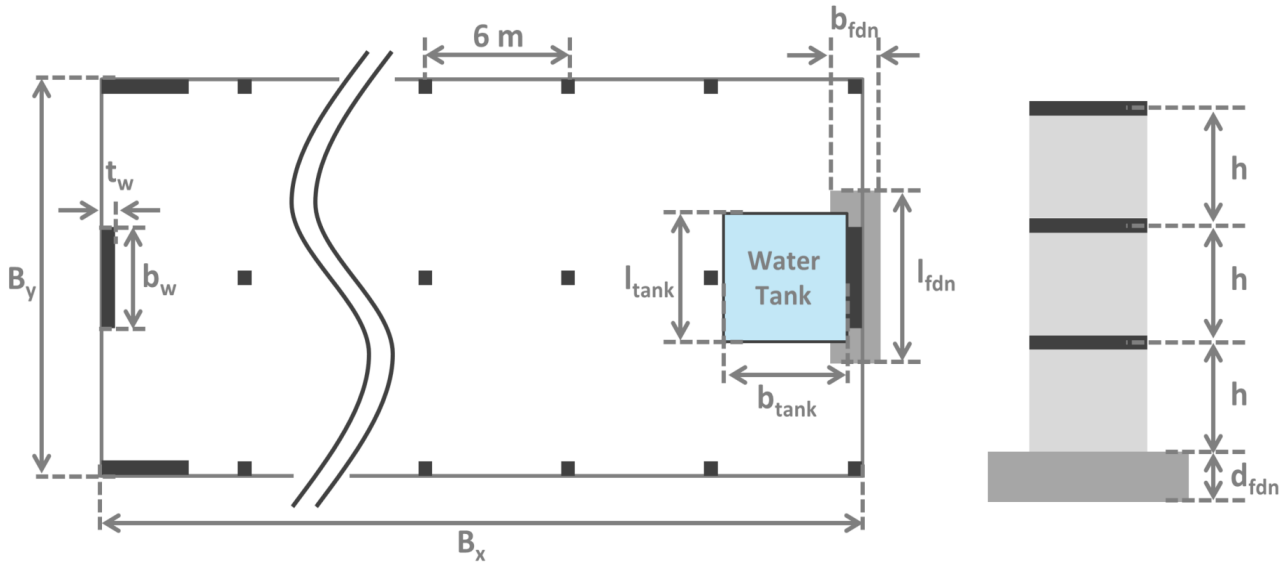

Figure 1 : Design example : 3 storey building

1. Design Situation

1-1. Design Parameters

Basic geometry

Number of stories	$n := 3$
Length	$B_x := 48\,\mathrm{m}$
Width	$B_y := 15\,\mathrm{m}$

Number of bays in long direction $N_x := 8$

Number of bays in short direction $N_y := 2$

Height of each storey $h := 3.2\,m$

Thickness of floor $d_{floor} := 250\,mm$

Shear wall

Thickness $t_w := 300\,mm$

Width $b_w := 4\,m$

Water tank

Depth $d_{tank} := 2\,m$

Length $l_{tank} := 5\,m$

Width $b_{tank} := 5\,m$

Strip foundation

Length $l_{fdn} := 6.5\,m$

Breadth $b_{fdn} := 2\,m$

Thickness $d_{fdn} := 1.5\,m$

Characteristic of imposed/wind actions

Roof loading $q_{rf\_k} := 0.6\,kPa$

Office floor loading $q_{off\_k} := 2.5\,kPa$

Partition loading $q_{par\_k} := 0.8\,kPa$

Wind $q_{w\_k} := 1.15\,kPa$

Weight density

Reinforced concrete $\gamma_{c\_k} := 25\ \frac{kN}{m^3}$

Water $\gamma_{w\_k} := 10\ \frac{kN}{m^3}$

Area

Total plan area of building $A_{tot} := B_x \cdot B_y = 720\ m^2$

Area above the stability wall $A := \frac{B_y + b_w}{2} \cdot \frac{1}{2} \cdot \frac{B_x}{N_x} = 28.500\ m^2$

1-2. Characteristic Actions - Permanent

Self weight of slabs

Floor $g_{fl\_Gk} := \gamma_{c\_k} \cdot d_{floor} = 6.25\ kPa$

Screed on roof $g_{scr\_Gk} := 1.5\ kPa$

Raised floor $g_{r\_fl\_Gk} := 0.5\ kPa$

Self weight of others

Water tank on roof $W_{tank\_Gk} := \frac{1}{2} \cdot \gamma_{w\_k} \cdot d_{tank} \cdot l_{tank} \cdot b_{tank} = 250\ kN$

Core wall $W_{wall\_Gk} := \gamma_{c\_k} \cdot t_w \cdot b_w \cdot (n \cdot h) = 288.000\ kN$

Pad foundation $W_{fdn\_Gk} := \gamma_{c\_k} \cdot d_{fdn} \cdot b_{fdn} \cdot l_{fdn} = 487.500\ kN$

Total self weight

Total self weight on removable members

$N_{Gk1} := (n \cdot g_{fl\_Gk} \cdot A) + (g_{scr\_Gk} \cdot A) + W_{wall\_Gk} + W_{fdn\_Gk}$

$N_{Gk1} = 1.353 \times 10^3\ kN$

Total self weight of removable members

$N_{Gk2} := ((n - 1) \cdot g_{r\_fl\_Gk} \cdot A) + W_{tank\_Gk}$

$N_{Gk2} = 278.500\ kN$

1-3. Characteristic Actions - Variable

Imposed actions (normal to ground)

on roof $N_{rf\_Qk} := q_{rf\_k} \cdot A = 17.100\ \text{kN}$

on floors $N_{fl\_Qk} := (n-1) \cdot (q_{off\_k} + q_{par\_k}) \cdot A = 188.100\ \text{kN}$

Wind actions (horizontal direction)

on roof $Q_{w\_rf\_Qk} := q_{w\_k} \cdot \frac{h}{2} \cdot \frac{B_x}{2} = 44.160\ \text{kN}$

on each floor $Q_{w\_fl\_Qk} := q_{w\_k} \cdot h \cdot \frac{B_x}{2} = 88.320\ \text{kN}$

Total wind action (normal to ground)

$N_{w\_Qk} := 0\ \text{kN}$

Moment effect of wind action

first floor $M_{w\_Qk1} := Q_{w\_fl\_Qk} \cdot ((n-2) \cdot h + d_{fdn})$

$M_{w\_Qk1} = 415.104\ \text{kN·m}$

second floor $M_{w\_Qk2} := Q_{w\_fl\_Qk} \cdot ((n-1) \cdot h + d_{fdn})$

$M_{w\_Qk2} = 697.728\ \text{kN·m}$

roof $M_{w\_Qk3} := Q_{w\_rf\_Qk} \cdot (n \cdot h + d_{fdn})$

$M_{w\_Qk3} = 490.176\ \text{kN·m}$

total $M_{w\_Qk} := M_{w\_Qk1} + M_{w\_Qk2} + M_{w\_Qk3}$

$M_{w\_Qk} = 1.603 \times 10^{3}\ \text{kN·m}$

2. Combination of Actions for Persistent and Transient Design Situations - ULS (Ultimate Limit State) Verification

2-1. Combination 1

Wind as leading variable action / Vertical actions unfavorable / Partial factors from Set B

Partial factors

on permanent actions	$\gamma_G := 1.35$
on variable actions (wind)	$\gamma_{Q\_w} := 1.5$
on variable actions (imposed loads)	$\gamma_{Q\_i} := 1.5$

Combination factors

for wind	$\psi_w := 1.0$
for imposed load in office areas (Category B)	$\psi_{fl} := 0.7$
for imposed load on roof (Category H)	$\psi_{rf} := 0$

Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$$N_{Ed} = 2.400 \times 10^3 \ \mathrm{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 2.405 \times 10^3 \ \mathrm{kN \cdot m}$$

Maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} + \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^2} = 355.313 \ \mathrm{kPa}$$

2-2. Combination 2

Wind as leading variable action / Vertical actions favorable / Partial factors from Set B

Partial factors

on permanent, favorable $\gamma_{G\_fav} := 1.0$

Design value of normal action effect

$N_{Ed} := \gamma_{G\_fav} \cdot \left(N_{Gk1} + N_{Gk2} \right) = 1.631 \times 10^{3}\ \mathrm{kN}$

Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 2.405 \times 10^{3}\ \mathrm{kN \cdot m}$

Maximum bearing pressure on underside of foundation

$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} - \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^{2}} = -45.263\ \mathrm{kPa}$

Line of action is outside the middle-third and eccentricity

$ecc := \frac{M_{Ed}}{N_{Ed}} = 1.474\ \mathrm{m}$

Revised maximum bearing pressure on underside of foundation

$P_{max\_Ed} := \frac{8}{3} \cdot \frac{N_{Ed}}{\left(l_{fdn} - 2 \cdot ecc \right)^{2}} = 344.810\ \mathrm{kPa}$

2-3. Combination 3

Imposed loads as leading variable action / Vertical actions unfavorable / Partial factors from Set B

Combination factors

for wind	$\psi_w := 0.6$
for imposed load in office areas (Category B)	$\psi_{fl} := 1$
for imposed load on roof (Category H)	$\psi_{rf} := 1$

Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$$N_{Ed} = 2.510 \times 10^3 \ \mathrm{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 1.443 \times 10^3 \ \mathrm{kN \cdot m}$$

Maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} + \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^2} = 295.504 \ \mathrm{kPa}$$

2-4. Combination 4

Wind as leading variable action / Vertical actions unfavorable / Partial factors from Set C

Partial factors

on permanent actions	$\gamma_G := 1$
on variable actions (wind)	$\gamma_{Q\_w} := 1.3$
on variable actions (imposed loads)	$\gamma_{Q\_i} := 1.3$

Combination factors

for wind	$\psi_w := 1.0$
for imposed load in office areas (Category B)	$\psi_{fl} := 0.7$
for imposed load on roof (Category H)	$\psi_{rf} := 0$

Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$$N_{Ed} = 1.802 \times 10^3 \ \mathrm{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 2.084 \times 10^3 \ \mathrm{kN \cdot m}$$

2-5. Combination 5

Wind as leading variable action / Vertical actions favorable / Partial factors from Set C

Design value of normal action effect

$$N_{Ed} := \gamma_{G\_fav} \cdot \left(N_{Gk1} + N_{Gk2} \right) = 1.631 \times 10^{3}\ \mathrm{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 2.084 \times 10^{3}\ \mathrm{kN \cdot m}$$

2-6. Combination 6

Imposed loads as leading variable action / Vertical actions unfavorable / Partial factors from Set C

Combination factors

for wind	$\psi_{w} := 0.6$
for imposed load in office areas (Category B)	$\psi_{fl} := 1$
for imposed load on roof (Category H)	$\psi_{rf} := 1$

Design value of normal action effect

$$N_{Ed} := \gamma_{G} \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_{w} \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$$N_{Ed} = 1.898 \times 10^{3}\ \mathrm{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 1.250 \times 10^{3}\ \mathrm{kN \cdot m}$$

3. Combination of Actions for Quasi-Persistent Design Situations - SLS (Serviceability Limit States) Verification

3-1. Combination 7

Wind as leading variable action / Vertical actions unfavorable / Partial factors from SLS

Partial factors

on permanent actions	$\gamma_G := 1$
on variable actions (wind)	$\gamma_{Q\_w} := 1$
on variable actions (imposed loads)	$\gamma_{Q\_i} := 1$

Combination factors

for wind	$\psi_w := 0$
for imposed load in office areas (Category B)	$\psi_{fl} := 0.3$
for imposed load on roof (Category H)	$\psi_{rf} := 0$

Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$N_{Ed} = 1.688 \times 10^3$ kN

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 0.$$

3-2. Combination 8

Wind as leading variable action / Vertical actions favorable / Partial factors from SLS

Design value of normal action effect

$$N_{Ed} := \gamma_{G\_fav} \cdot \left(N_{Gk1} + N_{Gk2} \right) = 1.631 \times 10^{3}\ \text{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 0.$$

3-3. Combination 9

Imposed loads as leading variable action / Vertical actions unfavorable / Partial factors from SLS

Combination factors

for wind	$\psi_{w} := 0$
for imposed load in office areas (Category B)	$\psi_{fl} := 0.3$
for imposed load on roof (Category H)	$\psi_{rf} := 0$

Design value of normal action effect

$$N_{Ed} := \gamma_{G} \cdot \left(N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_{w} \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$$

$$N_{Ed} = 1.688 \times 10^{3}\ \text{kN}$$

Design value of moment effect

$$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 0.$$